Inkjet Printed Color Filter for LCD TV Application

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Abstract

Inkjet printing technology is a highly proprietary process. We have evaluated the possibility of using inkjet technique to prepare color filters. Product specification for TV application was used as a template to examine process capability. Technical aspects of ink composition, jetting ability, and surface interaction were discussed.

1. Introduction

Today, information display in electronic format is one of the major technologies and economical driver. Flat panel display is popular in its nature of thin, lightweight for anywhere, anytime purpose. Large area panel application is recently stimulated by HDTV broadcasting system with LCD TV integration. It is expected that the sale of LCD TV unit will be increased from 167 million now to 476 million in 2007.

In the transition from conventional CRT to LCD, there are several technical obstacles need to be addressed. One of the challenges is to produce large area LCD cost effectively for general public acceptance.

Color filter is one of the major components in LCD TV for fidelity color expression, it also constitute 24 % of overall panel cost. In successful implementation of color filter for TV application, a new stringent color filter specification must be met, criteria such as color purity, transparency, and color reproduction.

Color filter, today in majority, is produced by a pigment dispersion method, a repeated photolithography subtractive process to ensure product reliabilities and high definition. Advanced color filter fabrication plant had been set up to meet current market expansion. As substrate size reaching

1500x1850 mm, a more selective and efficient alternative, inkjet printing, for color deposition is sought.

2. Objective

In our efforts in inkjet applications, we have identified that ink formulation as one of the key factors for successful product fabrication. By understanding intrinsic ink properties, it is possible to tailor nozzle jetting and substrate surface compatibility. So that, printing accuracy can be compensated by a self-aligned color ink. And the color reproducibility of this color filter is secured.

In this paper, we would demonstrate that a color filter fabrication for TV application using inkjet printing technique.

3. Ink Deposition

In the preparation of color filter using inkjet printing method, color ink is discharged from a micro nozzle to fill a cell confined by black resin matrix grid. For accurate pixel array inkjet printing color deposition, precise pixel alignment and consistent ink jetting are technical prerequisites. Figure. 1.

(A) (B)

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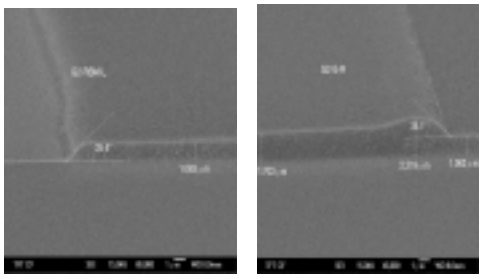

Figure. 1 (A) RBM before color deposition (B) RBM after color deposition.

To assist in alignment, the surface energy distribution among ink, black matrix, and glass need to be carefully defined. So that, color ink can be introduced without neighboring interference. In general, there is a need of homogeneous between ink and glass for maximum coverage, and of heterogeneous between ink and matrix grid for color separation. With proper ink composition, it is possible to achieve self-alignment and consistent jetting requirements.

Piezo inkjet printing parameters were optimized by repeated trials, such as actuating voltage, waveform, pulse width, and jetting frequency. Applied voltage and pulse width are related to piezo material deformation, so is ink quantity been discharged. Waveform affects the droplet speed released from nozzle, so to the impact energy on substrate. And jetting frequency is proportional to product throughput. In coordination with substrate carrier, a color filter fabrication system is realized.

Since the advantages of curing speed and the desired optical refractive index, photosensitive polyacrylate ink was employed in a piezo type inkjet printer. Surface tension and viscosity of ink were constantly monitored during printer jet ability development. However, other ink composition intrinsic properties cannot be overlooked for jetting stability.

4. Surface Characterization

Ink is normally composed by pigment, binder, and solvent. Since solvent constitute majority of inkjet ink composition, it is necessary to apply solvent mixture and cross-linking agents to ensure surface profile uniformity and to facilitate curing process after color deposition. By proper solvent mixture selection, solvent evaporation induced coffee ring phenomenon can be reduced. Figure 2.

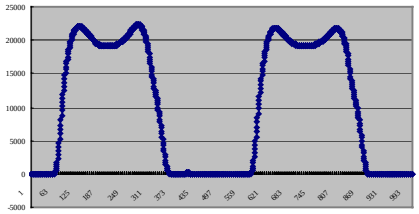

Figure 2 Color ink drying surface profile

Surface roughness of a color filter affect color wavelength dispersion. To avoid color contamination in final product performance, roughness needs to be constrained within specification. The root causes of this roughness issue resulted from particle size of pigment and the distribution technique used to disperse them. By proper formulate ink compositions; surface roughness of color filter can be controlled. Figure 3.

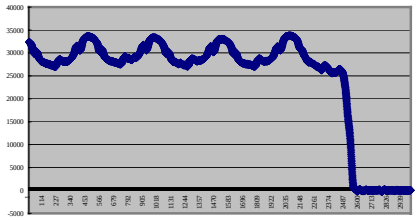

Figure 3 Color ink drying surface roughness

It is important to achieved uniformity both within pixel and panel. Any surface profile deviation can contribute to cell gap non-uniformity within panel, which tends to deteriorated liquid crystal molecule orientation and distribution in cell. In our inkjet printing experiments, we recognized that each individual nozzle head droplet size deviations inherently from its producer need to be avoiding accumulation. This can be manipulated by software programming to fill one pixel with different nozzle. Figure. 4.

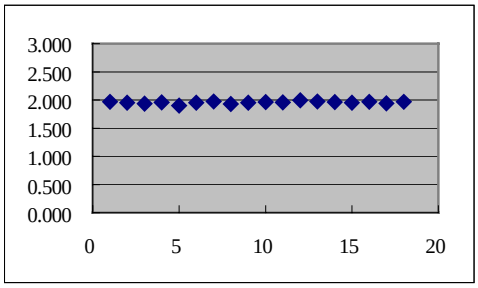

Figure. 4 Film Thickness Distributions

5. Color Purity

Color contamination in inkjet printing might be the results of jetting satellite droplet and droplet coalescent from adjacent pixel. Jetting satellite droplet can be reduced by fluid jetting mechanism modifications. These were to adjust process parameters of droplet forming and releasing from nozzle head.

Droplet coalescent from adjacent pixel problem was addressed by surface energy distribution. Color separation can be affected by introducing an ink-receiving layer to stabilized surface energy. Plasma surface treatment to differentiate glass substrate and black matrix was also successful. In essential, color resist formulation with hydrophobic and hydrophilic to RGB has also added a new dimension to inkjet color resist deposition. Figure 5

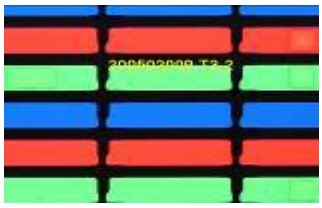

Figure 5 Finished Product

In consideration of color purity of color resist, several pigments mixture are needed to obtain correct color coordinate for accurate RGB color expression. The ideal color filter would be only transmitted to certain wavelength of light. These critical high aspect ratio of RGB transparency requirements are complicated interactions of color resist compositions.

While increase optical density by increasing color resist thickness, brightness is traded off. To achieve optical density with minimum resist thickness has been an ultimate goal for technical development. Intrinsic pigment property is a major factor for color expression. One of the methods to improve color expression is to modify pigment purity and particle size. A color filter with increasing optical density and expanded color gamut suitable for LCD TV application can be obtained. Figure. 6.

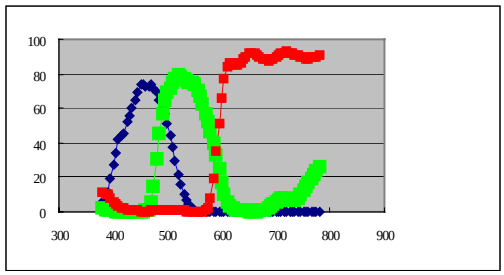

Figure. 6 Transmittance % vs. Wavelength nm

6. Color Reproduction

For a typical 19” SXGA color filter to be fabricated with inkjet printing method, colored ink need to be precisely ejected and filled in sub pixel dimension of about 300x300 um, and fill array of 1280x1024x3 sub pixels with thickness uniformity variation in 3%.

For such stringent requirements, technical aspects of color resist, printing head, and substrate carrier must be well coordinated. The advantage of Inkjet printing technologies was attested by recent large area color filter for LCD TV application.

		R	G	B	Gamut
NTSC	x	0.67	0.21	0.14	100%
	y	0.33	0.71	0.08	
Product	x	0.652	0.297	0.134	72%
	y	0.33	0.588	0.111	

Table 1 Color Gamut Correspondent to NTSC

It is necessary to intensify both optical density and brightness of current color filter for TV application. However, in combination with strong backlight to achieve brightness requirement, color temperature and color tone shifted to a less color reproduction range. While increasing color resist thickness, brightness level was reduced. After all, a color resist with new sets of chromaticity coordinate is required for LCD

TV color filter.

While the liquid crystal display devices for desktop monitors require a color reproducibility of 50 to 65% in NTSC (National Television System Committee) ratio. Liquid crystal television sets require a wider range of color reproducibility of 60 to 75% in NTSC. Table 1. In addition, a brightness level of 500 nits and a contrast ratio of 600 are needed for a liquid crystal TV application.

7. Impact

Inkjet printing provides an indispensable method for color filter fabrication. It is flexible in printing material and pattern design.

Color filter may be produced by a printing method in which red, green and blue inks are inkjet printed on a glass substrate respectively. This method has provided a simple selective additive process for color filter production.

Advantages included lower equipment capital investment by eliminating photolithography process, lower process cost by effective material usage, and reduce waste for environmental friendly.

8. Conclusion

Inkjet printing technology is a highly proprietary process. We have evaluated the possibility of using inkjet technique to prepare color filter. Product specification for TV application was used as a template to examine process capability. Technical aspects of ink composition, jetting ability, and surface interaction were explored.

Inkjet printing provides an indispensable method for color filter fabrication. It is flexible in printing material and pattern design. In the process of color filter product development, a total solution of photo spacer inkjet printing remains an interesting topic to investigate.

9. Acknowledgements

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